

AD-A123 533

MCCLELLAN-KERR RIVER NAVIGATION SYSTEM BANK
STABILIZATION(U) ARMY ENGINEER INST FOR WATER RESOURCES
FORT BELVOIR VA R SUMMITT MAR 88 IMR-RR-88-R3

1/1

UNCLASSIFIED

F/G 13/2

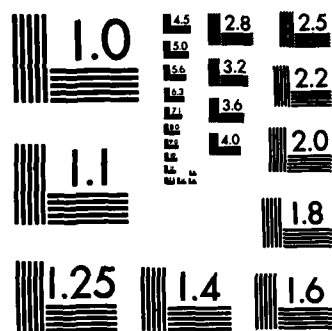
NL



END

FILMED

1 DTC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ADA 123533

McCLELLAN-KERR RIVER
NAVIGATION SYSTEM

BANK STABILIZATION

Approved for public release; distribution unlimited



DTIC
ELECTE
S D
JAN 18 1983

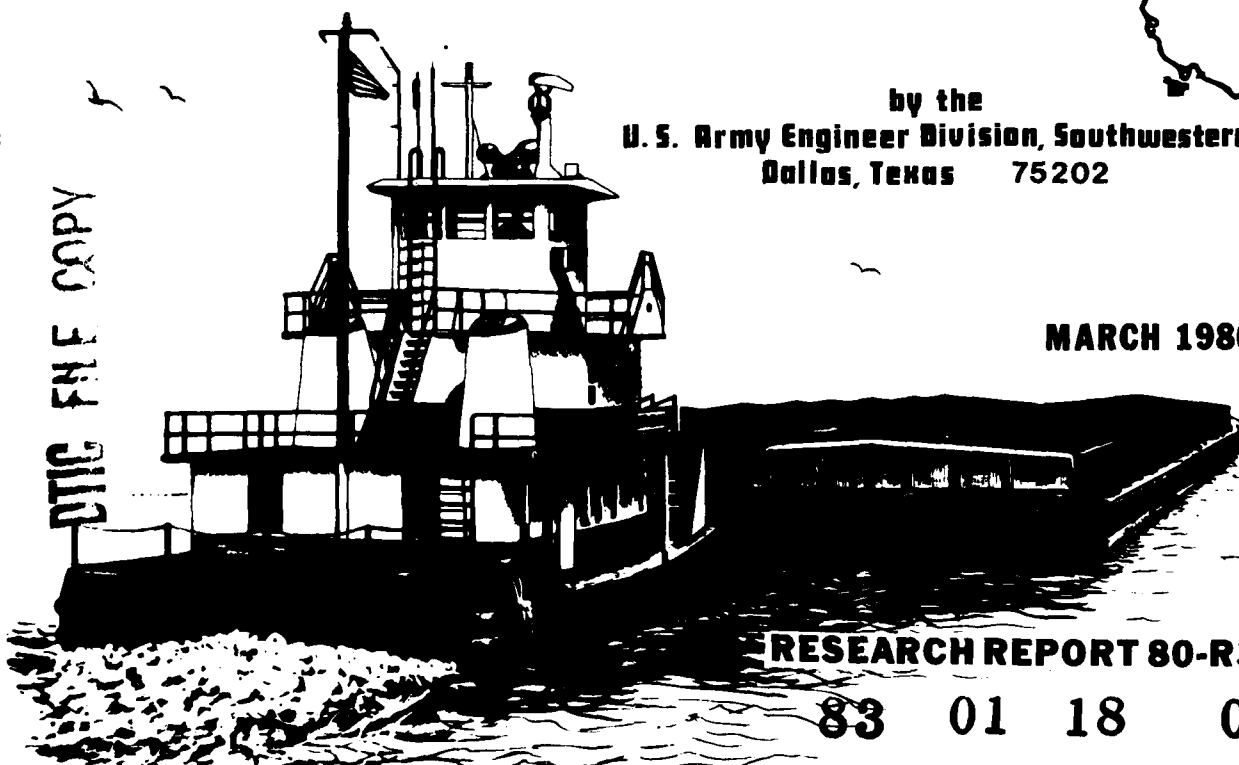
Submitted to:
U. S. ARMY ENGINEER
INSTITUTE FOR
WATER RESOURCES
KINGMAN BUILDING
FORT BELVOIR VIRGINIA 22060



by the
U. S. Army Engineer Division, Southwestern
Dallas, Texas 75202

MARCH 1980

DTIC FILE COPY



RESEARCH REPORT 80-R3

83 01 18 009

Copies may be purchased from:

National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22151

This report is not to be construed as necessarily representing the views
of the Federal Government nor of the U.S. Army Corps of Engineers.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER IWR Research Report 80-R3	2. GOVT ACCESSION NO. AD-A123533	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) McClellan-Kerr River System		5. TYPE OF REPORT & PERIOD COVERED Research
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s) 80-R3
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer Division, Southwestern Dallas, Texas 75202		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer, Institute for Water Resources Fort Belvoir, VA 22060		12. REPORT DATE March 1980
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 27
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Unlimited		
<div style="border: 1px solid black; padding: 5px; display: inline-block;">DISTRIBUTION STATEMENT A Approved for public release Distribution Unlimited</div>		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Dr. Robert Summitt was principal author and project manager.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Project Development Upstream & Tributary Reservoirs Project Benefits Physical & Environmental Effects Need for Bank Stabilization Economic Effects Work Completed		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report is to present data and information which reveal the nature and extent of the effect of the bank stabilization works, as an integral part of the McClellan-Kerr Arkansas River Navigation Project. Identifying economic effects will be the primary thrust of this report. 9		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	



McClellan-Kerr River

Navigation System

BANK STABILIZATION

A Report Submitted to the:
 U.S. Army Engineer Institute for Water Resources
 Kingman Building
 Fort Belvoir, Virginia 22060

by the
 U.S. Army Engineer Division, Southwestern
 Dallas, Texas 75202

March 1980

IWR Report 80-R3

BANK STABILIZATION

McClellan-Kerr River Navigation System

<u>TABLE OF CONTENTS</u>	<u>PAGE</u>
I. INTRODUCTION	1
Purpose	1
Project Development	1
Project Benefits	1
II. BANK STABILIZATION WORK	4
Need	4
Work Completed	7
Upstream & Tributary Reservoirs	8
III. BANK STABILIZATION EFFECTS	8
Physical & Environmental	8
Land Changes	8
Turbidity	10
Vegetation	11
Summary	11
Economic Effects	12
Damages Prevented	14
Land Accruals	14
IV. SUMMARY & CONCLUSIONS	19

TABLESPAGE

1. Summary of Major Capital Costs of the McClellan-Kerr Arkansas River Navigation System.	2
2. Annual Benefits from Construction	3
3. Average Annual Charges.	3
4. Sediment Measures by Year	10
5. Volume of Maintenance Dredging Completed to Provide Adequate Navigation Channel, Below Ft. Smith, 1971-1977	13
6. Estimated Future Average Annual Bank Erosion Losses . . .	15
7. Prevention of Loss of Land from Bank Erosion by Bank Stabilization Work	16
8. Usable Land Accruals from Bank Stabilization Works and Cutoffs	17

FIGURES

1. Illustration of a Proposed Stone-filled Dike and Revetment Plan.	6
2. General Plan and Profile - Arkansas River and Tributaries	9

BANK STABILIZATION

McClellan-Kerr River Navigation System

I. INTRODUCTION.

Purpose. The purpose of this study and report is to present data and information which reveal the nature and extent of the effect of the bank stabilization works, as an integral part of the McClellan-Kerr Arkansas River Navigation Project. Identifying economic effects will be the primary thrust of this report, with limited treatment of the physical and environmental effects. Environmental aspects are the subject of another specific study and report contracted by the Little Rock District, Corps of Engineers.

Project Development. The development of the Arkansas River for navigation, flood control, hydroelectric power generation and other purposes was the largest civil works project ever undertaken by the Corps of Engineers. It was authorized by Congress in the River and Harbor Act of July 24, 1946, and construction began in 1949. In 1971 Congress designated it as the McClellan-Kerr Arkansas River Navigation System. Navigation reached Little Rock, Arkansas, in December 1968; Fort Smith, Arkansas, in December 1969; and Catoosa, Oklahoma, at the head of navigation, in December 1970. A minimum depth of 9 feet is maintained along the navigation channel, and the width of the channel varies from 300 feet in the White River and the Arkansas Post Canal to 250 feet on the Arkansas River and 150 feet on the Verdigris.

Although seven upstream lakes in eastern Oklahoma have a major role in the operation of the McClellan-Kerr Arkansas River Navigation System, only three lakes are a part of the Navigation System. Keystone Lake is located on the Arkansas River above Tulsa, Oklahoma, Oologah Lake on the Verdigris River and Eufaula Lake on the Canadian River. The purposes of these lakes include navigation, flood control, municipal and industrial water supply, hydroelectric power, recreation, and fish and wildlife.

Project Benefits. This completed project includes multiple benefits which accrue from low-cost water transportation, reduction of flood damages, generation of hydroelectric power, channel stabilization, provision of water supply, enhancement of fish and wildlife, recreation, and redevelopment. The type of the specific benefit determines the nature and extent of the effects from each. For example, flood damage reduction and water supply storage supplied affect the local and regional areas in Arkansas and Oklahoma, while hydroelectric power produced is distributed in Arkansas, Kansas, Texas, Oklahoma, Missouri and Louisiana. Reduced cost of water transportation has widespread effects upon economies of the region, the Nation, and international trade.

Barge traffic on the entire 448-mile McClellan-Kerr Arkansas River Navigation System carried 5.7 million tons of freight during 1972, the second year of operation of the full waterway. In 1978 slightly more than 10.0 million tons of commerce were shipped on the waterway. The commercial activity includes movements of coal, iron, and steel, rock, sand, fertilizer, chemicals, petroleum, paper, soybeans, bauxite, lumber, grain, and miscellaneous commodities. A water traffic projection issued by the Corps of Engineers in 1965 shows that total annual shipments on the waterway are expected to reach 13.2 million tons in the 14th year of operation.

The estimated cost of the project was \$1,258,244,000, see Table 1. Of this amount, about 47 percent of total cost of the work was done in the Tulsa District, and about 53 percent was done in the Little Rock District. The benefit-to-cost ratio was calculated at 1.5 to 1.0, based on July 1968 price levels and a 100-year project life.

Table 1. SUMMARY OF MAJOR CAPITAL COSTS OF THE McCLELLAN-KERR ARKANSAS RIVER NAVIGATION SYSTEM.

<hr/>	
<hr/>	
Upstream Lakes	\$290,676,000
Main Stem Lakes	341,300,000
Locks and Dams	494,000,000
Bank Stabilization and Channel Rectification	130,000,000
Navigation Aids	<u>2,268,000</u>
Total	\$1,258,244,000
<hr/>	

Source: McClellan-Kerr Arkansas River Navigation System, Arkansas and Oklahoma, pertinent data for testifying officers, Little Rock District, 1 January 1973.

Annual benefits which were estimated to result from construction and operation of the project as a whole, are as follows:

Table 2
Annual Benefits from Construction

(1968 Prices)

Savings in transportation	\$40,470,000	53.75
Power value	14,838,900	19.71
Flood control benefits	6,602,600	8.77
Channel stabilization	6,575,000	8.73
Water supply	828,900	1.10
Fish and wildlife	312,000	0.41
Recreation	2,297,000	3.05
Redevelopment	3,355,800	4.45
TOTAL	\$75,280,200	100

Navigation benefits from savings in transportation costs represent about 54 percent of the total of the project's direct benefits, based on the annual commerce on the waterway which was estimated to eventually reach 13,200,000 tons by the 14th year of operation. The average annual charges for this project are indicated in Table 3.

Table 3
Average Annual Charges

<u>ITEM</u>	<u>DOLLAR COST</u>	<u>PERCENT</u>
Interest	\$31,085,700	60
Amortization	2,868,100	6
Operation and maintenance	15,643,000	31
Major replacements	805,200	2
Other	617,800	1
	\$51,019,800	100

Hydroelectric power represents almost 20 percent of the total project benefits. Annual flood control benefits represent about 9 percent of the total benefits attributed to the project. The upstream lakes in Oklahoma are operated in concert with other flood control projects in the Arkansas River Basin to control flows on the main stem and its tributaries. About 8 percent of benefits attributed to the project include recreation, fish and wildlife conservation, soil erosion control, and municipal and industrial water supply storage space.

About 9 percent of the benefits ascribed to the total project are assigned to channel stabilization. In its natural state, the Arkansas River was unstable and presented almost insurmountable problems in

making it suitable for navigation. Carrying a heavy sediment load and subject to wide and frequent fluctuations, the river could change from a mere trickle of water to a rushing torrent, switching its course and destroying improvements along its banks. Bank stabilization and channel rectification works now provide a relatively stable channel suitable for modern barge traffic. Revetments, dikes, channel cutoffs, and dredging stabilize the banks, as well as realign and deepen the designated navigation channel. Control of the channel width and depth allows more efficient use of water releases necessary for maintaining minimum depths and width for navigation on the waterway. Dredging is required to assist in the establishment of a long-term stabilized channel.

II. BANK STABILIZATION WORK

The Arkansas River is an alluvial stream. An alluvial stream is defined as one flowing in a channel formed by the stream in sedimentary material previously transported and deposited by the stream. Alluvial rivers are characterized by their meandering habits. An appreciation of the meandering formation and the principal factors affecting meanders and caving banks is a prerequisite to understanding of the various changes that occur when a channel is stabilized. The types of meanders normally found along alluvial rivers creates or forms bars, beaches, and traveling bars. The Arkansas River is considered a medium size alluvial river.

An examination of the Arkansas River before stabilization and rectification was completed will contribute to understanding changes attributable to bank stabilization works. The preproject suspended sediment load was 105 million tons per year at Little Rock. About 24 percent of this sediment was suspended bed material consisting primarily of sand. The sediment was obtained from caving the banks and removal of material from the bottom of the river. The river picks material at one location and then deposits it downstream at another location depending on the characteristics of the river. The cycle is then repeated downriver. How the river moves material along its path depends on several factors; the major ones being the volume of flow, the water surface slope, and the size of material in the river channel.

Need. Information from Congressional House Document No. 758 made specific mention of project aspects which reveal the need for sediment control and bank stabilization.

The records of past attempts to improve the Arkansas River for navigation by snagging, dredging, and regulation, together with the knowledge of the characteristic periods of low flow and large sediment load of the stream, show conclusively that the only practicable method of providing for dependable navigation is by canalization with adequate provisions for sediment control.

....Extensive bank-stabilization works would be required in the reach of the waterway from the mouth of the Verdigris River to the Mississippi River....

The program for stabilization of the Arkansas River is necessary for providing a navigation channel 9 feet deep primarily from about 35 miles west of Fort Smith, Arkansas, to the Mississippi River. Figure 1 illustrates dikes and revetments, the two basic types of structures used to assist in stabilizing stream flows. Between Fort Smith and Little Rock, Arkansas, the river flows through a mountainous area. The alluvial flood plain in this area varies from 1/2 mile to 6 miles in width and is bounded by shale and sandstone hills and mountains. Bedrock is from 5 to 30 feet below the bottom of the riverbed during low water periods. Immediately downstream from Little Rock, the river enters the Mississippi River Alluvial Valley. On the south side of the river between Little Rock and Pine Bluff, the flood plain is limited by marine clay bluffs. On the north side of the river in this reach and below Pine Bluff, the flood plain is wide and generally unlimited. With the exception of a few areas where the resistant marine clay is present in the streambed, the depth of riverbed scour is limited only by the erosive capacity of the stream itself and amounts to more than 50 feet below low water level at some places.

The River carries a huge sediment load, estimated preproject to average 105,000,000 tons per year at Little Rock. As is characteristic of such a heavily laden stream, the river channel before stabilization was subject to extensive bank caving and shifting through its alluvial valley of sand, silt and clay. In the past, levee setbacks have been necessary along the river in order to prevent destruction of the levees. The bank stabilization work that has been completed has precluded the necessity of additional setbacks. In addition, caving banks have damaged numerous water, oil and gas pipeline crossings and have threatened to cause flanking of a number of bridges. Large areas of productive farmland were lost each year. Bank recession of 200 to 300 feet during a single rise was a common occurrence, and recession of as much as 1,200 feet during a single flood period was experienced prior to bank stabilization work. All this points up the necessity of bank stabilization and channel rectification work in order to: (1) obtain a stable channel suitable for navigation, (2) prevent flanking of the locks and dams and of bridges, and (3) prevent the continuing destruction or setting back of levees, damages to pipeline crossings, and loss of productive farmland and buildings.

The general procedure for stabilizing the Arkansas River involved shaping the stream into one channel along an alignment consisting of a series of moderate bends and permanently fixing the channel on that alignment. One of the essentials for maintaining such an alignment

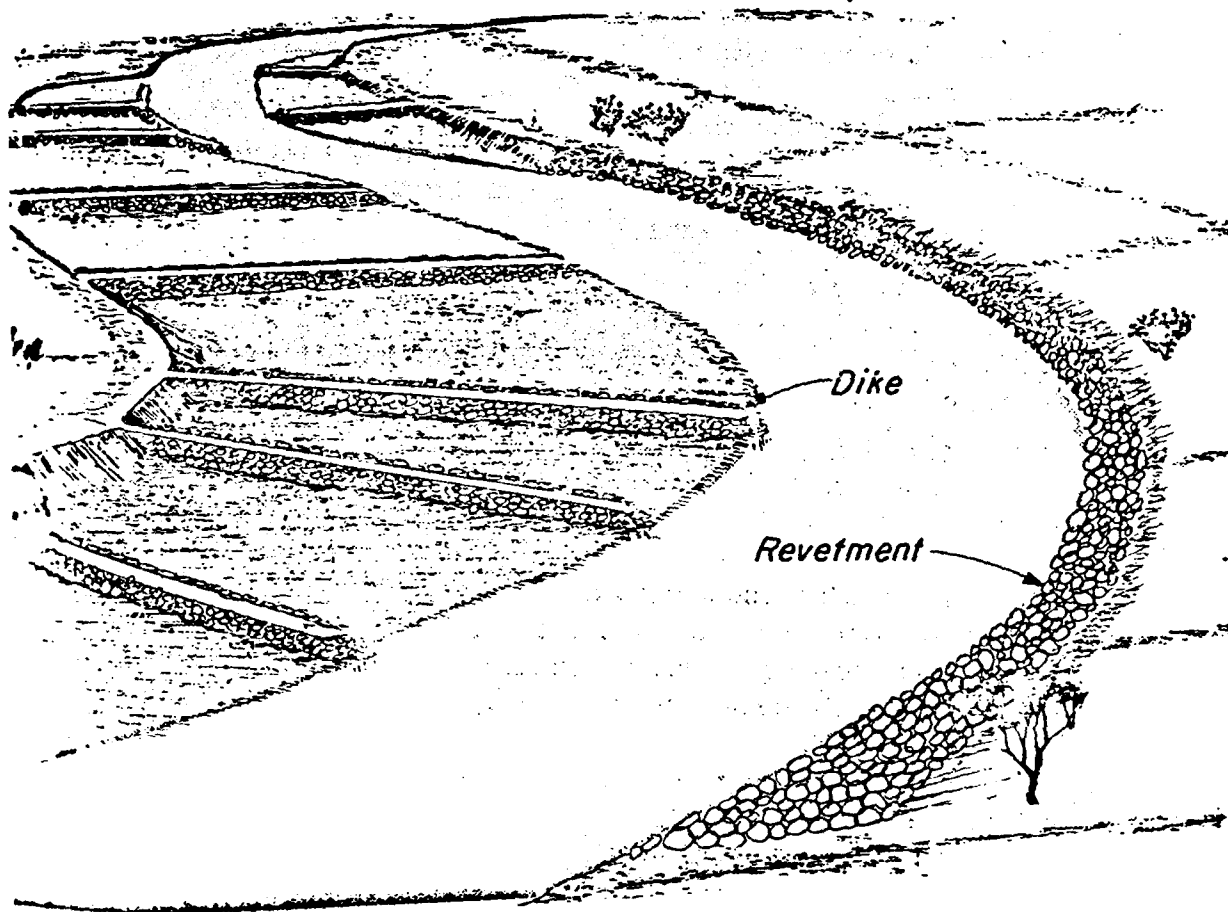


Figure 1. ILLUSTRATION OF A PROPOSED STONE-FILLED DIKE & REVETMENT PLAN

is that stabilization work in any section of the river be started at some fixed point, such as a natural rock outcrop or a manmade structure, upstream and worked progressively downstream to some other fixed location. Another important design procedure: "To the extent possible, the bend alignments were designed to follow the natural alignment of the river so as to minimize changes to the flow regime or characteristics of the river."^{1/} This has been accomplished by the use of: (1) revetments to stabilize the concave banks of bends, (2) dikes to close off secondary channels, to control the direction of flow from one bend to the next, and to fair-out the natural concave banks to a more desirable alignment, and (3) cutoff channels to eliminate long bends with small radii of curvature.

The Arkansas River is still subject to some shifting of alignment within the present control lines. Deviations, if left uncontrolled, may allow a deterioration of the alignment for the navigation channel and would permit severe damage to existing bank-stabilization structures. Minor additional contraction structures may be required to correct such deviations and also to improve navigation conditions in reaches where shoals have developed repeatedly and maintenance dredging has been required.

The Federal Government, together with local improvement districts, have invested more than \$37,000,000 in the construction of levees to protect more than two and one-half million acres of agricultural and urban lands within the flood plain of the river between Tulsa and the mouth. Also, there were 118 crossings of the River in 1975 between Tulsa and the mouth, about 95 of these are in the Little Rock District area. These crossings consist of highways, railways, pipelines, waterlines, and transmission lines. Many of the pipelines carry petroleum products, including natural gas, to large industrial centers in the northern and eastern states. The loss of these crossings would have a far-reaching effect on a wide area of the nation and an immediate impact on military installations and defense industries. The construction of the bank stabilization work to date has resulted in its primary goal of establishing a stable navigation channel for about 336 miles along the river. This channel has provided dependable navigation since 1968 when the first portion of the waterway was opened and maintenance dredging has been slightly more than was anticipated because of the heavy sediment loads associated with high river flows. River banks along most of the channel have been stabilized, thereby preventing the loss of levees and much good farmland by bank caving. Before the stabilization work was built, caving banks destroyed levees or made it necessary to construct new levee setbacks to prevent flooding of large areas of valley land. The stabilized channel has also prevented damages and threats to the safety of bridges, powerlines and pipelines along the river.

Work Completed. Essentially all the bank stabilization work planned for the waterway has been completed. Within the Little Rock District,

^{1/} Source: Water Resources Development in Arkansas, 1973, Lower Mississippi Valley District, U.S. Army Corps of Engineers.

construction of dikes and revetments to stabilize the river banks and rectify the channel has been underway since 1949 with about 842,400 linear feet of dike and 1,324,900 linear feet of revetment included when the total work is accomplished over the navigation system from its beginning to mile 308 at Fort Smith, Arkansas, where Little Rock District responsibility ends and Tulsa District responsibility begins.

Upstream and Tributary Reservoirs. In addition to the four main stem reservoirs (Dardanelle, Ozark, Robert S. Kerr, and Webbers Falls), three reservoirs in eastern Oklahoma play a major role in the development and operation of the Arkansas River Navigation System. Keystone Reservoir is located on the Arkansas River above the navigable portion, and the other two reservoirs are located on its tributaries. These are Oologah on the Verdigris and Eufaula on the Canadian.

Other upstream reservoirs include Kaw on the Arkansas above Keystone, Tenkiller Ferry on the Illinois, and Pensacola, Markaham Ferry, and Fort Gibson on the Grand (Neosho) (Figure 2). These reservoirs were constructed to include low-flow regulation, sediment control, flood control, domestic and industrial water supply, enhancement of fish and wildlife habitat, recreation opportunities, and hydroelectric power generation.

III. BANK STABILIZATION EFFECTS

Physical and Environmental Effects. The bank stabilization and channel rectification program is an essential element of the multiple-purpose plan of development for the Arkansas River in Arkansas and Oklahoma which was authorized by the River and Harbor Act of 24 July 1946. A stable channel of suitable alignment, inherent in the development of a functional navigation project, is required to preclude flanking of the locks and dams as well as for navigation itself. Allowing the Arkansas River to flow in its natural uncontrolled state would not permit such beneficial uses of the channel.

Land Changes - Even though the river (in its uncontrolled state) caved banks as it flowed downstream, it did not change the total quantity of land. The amount of land in the river valley has remained relatively the same. However, the quality and quantity of productive land may vary significantly as the river meanders. As the river meandered across the valley, the banks caved at one location while a bar was built at another location. Many years will elapse before the quality of the land in these newly formed bars is as productive for agricultural uses as were the areas lost. The bank stabilization program has reduced the supply of sediment material the river may obtain from the banks and has decreased the angle of attack on sandbars in the river channel. Sediment storage in the upstream reservoirs has also sharply decreased the supply of material to the river. Within the stabilized channel the river now obtains most of its load from the bottom. The material from the bottom of the river is heavier and cleaner, leaving the flowing water cleaner.

McClellan-Kerr Arkansas River Navigation System

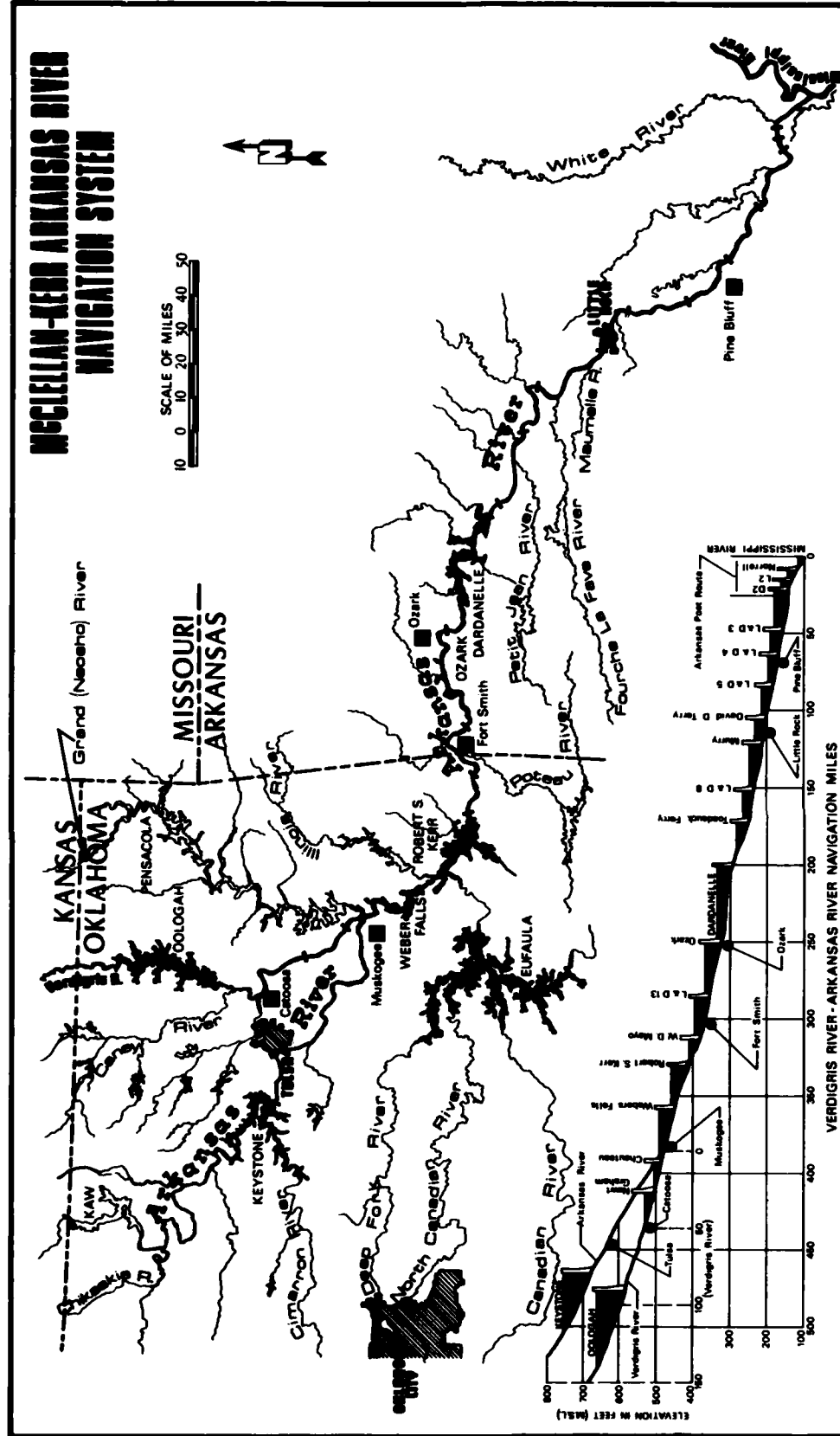


Figure 2
General Plan and Profile - Arkansas River and Tributaries

The bank stabilization and reservoirs appear to have influenced the turbidity. The upstream reservoirs remove some of the suspended sediment by detention. However, if the supply of sediment is available after the water is released from the reservoir, it may regain its full sediment load. The records indicate the stream flow is regaining less and less of its former load as the channel is making improvement at stabilizing as the supply of fine sediment is reduced. If the bank stabilization structures were not constructed, the banks would be caving as previously, the accrual of benefits from the project purpose of navigation would be greatly hampered, if not eliminated. The following figures will indicate how the supply of sediment material is being reduced. Tabulated in Table 4 are some quantities of sediment measured at selected gaging stations and the relation of streamflow and the amount of sediment moved.

Table 4
Sediment Measures by Year
Lock and Dam 13

<u>Water Year</u>	<u>River Flow Acre-Feet/Year</u>	<u>Sediment Ton/Year</u>	<u>Sediment Ton/Acre-Feet River Flow</u>
1971	14,460,000	3,784,400	.26
1973	51,150,000	36,441,400	.71
1975	46,870,000	14,408,100	.30
1976	14,990,000	2,036,200	.13

Dardanelle Lock and Dam

<u>Water Year</u>	<u>River Flow Acre-Feet/Year</u>	<u>Sediment Ton/Acre</u>	<u>Sediment Ton/Acre-Feet River Flow</u>
1964	7,142,000	5,203,000	.73
1969	34,540,000	6,813,700	.20
1973	55,640,000	11,283,600	.20
1976	15,850,000	602,109	.04

Little Rock; Murray Lock and Dam

<u>Water Year</u>	<u>River Flow Acre-Feet/Year</u>	<u>Sediment Ton/Acre</u>	<u>Sediment Ton/Acre-Feet River Flow</u>
1961	39,050,000	95,231,000	2.44
1964	21,030,000	21,552,000	1.02
1967	12,560,000	3,317,000	.26
1970	25,530,000	15,317,000	.60
1973	64,380,000	28,555,500	.44
1976	18,230,000	1,783,200	.01

Several factors influence the amount of material that the stream moves, such as the time of year of rises on the river and the size and duration of flow. However, the main control on the amount of sediment moved depends on the available supply. The supply will be picked up from the river bed and to some extent from the banks if it is available from either of these sources.

Vegetation - The bank stabilization and channel rectification has allowed the sandbars to stay at one location a sufficient length of time to grow willows, cottonwoods, and other types of plants. The vegetation on the bars reduces erosion during large flows on the river and removes some of the finer particles of sediment as the water flows through the growth on the bars. As the elevation of the top of the bars increases, it forces more of the flow to stay in the main channel when the next large flow occurs. The sandbars are generally divided into graveliferous, sand, and silt-clay-fine-sand layers. The finer material layers are the best to support vegetation and the vegetation is necessary to keep this material from being moved during the next large flow. This, in addition to the upstream reservoirs, reduces the turbidity in the river.

In a recent study entitled Environmental Effects of the Completed McClellan-Kerr Arkansas River Navigation System, there are some five major areas of effects which have been assessed. These are visual characteristics, bank stabilization, water quality, cultural, and ecology. The most significant visual changes identified were in the edge conditions and width of the waterway, in the vistas, in the grain character, and in the formation of in-stream lakes. The conclusion in this study was that bank stabilization had a positive effect on the Arkansas River in several ways, among which are a decreased turbidity, significant reduction in suspended sediment loads, and the formation of new habitat in backwater areas. The reduction in turbidity is linked to improved visual and aesthetic value as well as improved sport fishing. Prior to 1965, the average suspended sediment load ranged from 62 to 97 million tons/year whereas the estimate for the period 1965-1977 is only 10 million tons/year.

The backwater areas created by the dikes and revetments provide excellent habitat for fish and wildlife. There is some danger that routine and continued maintenance operations could destroy this habitat or prevent its effective use. In addition to providing valuable cover and spawning sites in the rock materials of the dikes and revetments, drift and debris tend to accumulate on or behind the pile and rockfill dikes which further augment these purposes.

Summary - The major physical effects of the Navigation Project include maintaining channel width and depth suitable for navigation, control of river flows (high and low), creation of on-stream and tributary lakes, restriction of natural river movements by bank stabilization works,

alignment of river channels which created old river-bend cutoff areas, reduction of quantity of sediments flowing downstream, improvement in water quality, as well as reduction in the flood damages. The environmental study referenced earlier concluded that the reduction in turbidity is linked to improved visual and aesthetic value, as well as improved sport fishing. Also, this study noted that the backwater areas created by the dikes and revetments provide excellent habitat for fish and wildlife.

The volume of maintenance dredging annually downstream from Fort Smith, Arkansas from 1971-1977 period is shown to vary from 1,000,000 cubic yards in 1971 to 4,500,000 cubic yards in 1973 when extremely high flows were experienced on the river (Table 5). The maintenance dredging volume from 1971 through 1977 averaged 2,470,000 cubic yards annually for the 7-year period. This average of 2.5 million cubic yards per year is slightly higher than the 2.2 million predicted in the design memorandum and is more than double the 1.2 million cubic yards annually predicted in 1964 by the Arkansas River Operation and Maintenance Committee for the years 1970-1975. The volume of maintenance dredging is expected to continue to decline as the amount of bed material in the channel approaches a near stable condition for the dominant flow regime of the Arkansas River. By the year 2000, much of the sediment storage in the larger reservoirs will be filled. Following that time sediment loads are anticipated to increase as less sediment is trapped.

Economic Effects. About seven, nine, and ten million tons of commerce were shipped by the waterway during 1976, 1977, and 1978, respectively, coming from or going to points in Illinois, Indiana, Missouri, West Virginia, Tennessee, Alabama, Arkansas, Oklahoma, Louisiana, Alabama, Texas, and Florida. Types of commodities moving by the waterway include iron and steel, coal, chemicals, sand and gravel, aggregate, rubber, fertilizers, petroleum, grains, wood and wood products, feed products, and other products. Five major public ports and a number of other ports are located along the navigation channel to handle tonnages shipped in and out of the area. Use of the waterway allows shippers to reduce their transport costs.

Hydroelectric power serves cities, industries and individuals in four states with electricity generated from a nonpolluting, renewable energy source. Recreation opportunities and its associated industries contribute significantly to the regional economy. A more stable water supply is provided to some cities as part of the great Arkansas Basin multiple-purpose plan from some upstream lakes.

Bank stabilization works make a significant contribution to the overall set of benefits which accrue to the entire System as a whole and are essential to maintaining a channel suitable for navigation, and the construction of bank stabilization and channel rectification has probably had the greatest impact upon water quality parameters, that is of decreasing turbidity and suspended sediment.

TABLE 5

VOLUME OF MAINTENANCE DREDGING COMPLETED TO PROVIDE
ADEQUATE NAVIGATION CHANNEL, BELOW FT. SMITH, 1971-1977

YEAR	MAINTENANCE DREDGING VOLUME				
	ANNUAL <u>1/</u> (Cu. Yrds.)	ACCUMULATIVE (Cu. Yrds.)	AVERAGE	PREDICTED <u>2/</u> BY ARK. R. O&M COMMITTEE	PREDICTED <u>2/</u> IN DESIGN MEMORANDUMS
1971	1,000,000	1,000,000	1,000,000		
1972	2,500,000	3,500,000	1,750,000	1,192,000	2,205,000
1973	4,500,000	8,000,000	2,670,000		
1974	4,300,000	12,300,000	3,080,000		
1975	1,400,000	13,700,000	2,740,000		
1976	1,900,000	15,600,000	2,600,000		
1977	1,700,000	17,300,000	2,470,000		
1980	-	-	-	896,000	
2010	-	-	-	896,000	

1/ Maintenance dredging completed to maintain navigable depths below Fort Smith, Arkansas.

SOURCE: 1/ Reports on Yearly Activities, of Arkansas River Basin Coordinating Committee, by SWD printed yearly 1972-1978.

2/ Maintenance Dredging on the Arkansas River Navigation Project August, 1975, US Army Corps of Engineers, Southwestern Division, Dallas, Texas, Table 1.

Damages Prevented - Flood damage prevention was estimated to occur from reduction and/or prevention of losses to lands, highways, railroads, utilities, levees and other properties from the mouth of the Verdigris River to the mouth of the Arkansas River, see Table 6. The losses estimated to occur were direct losses (\$1,541,600) and indirect losses (\$67,100) for the total direct and indirect losses (\$1,608,700). Forty-two percent of the direct losses were attributed to highways, railroads, utilities and other, while 24 percent of the losses were due to levee setbacks. Twenty-two percent of the estimated total direct losses were from lands and 12 percent were from bank protection works. The area under study is from about mile 309 to mile zero which is approximately the last two lines of Table 6. About three-fourths of all losses were expected to occur below mile 362, while one-fourth was expected to occur above mile 361.

A summary of all facilities, which cross the Arkansas River at various points, was developed from recent official Corps of Engineers Navigation Charts dated 1976. The summary of this publication reveals that 12 highway, 10 railroad, 63 utility, and 10 other crossings are presently in use as of July 1976 from Fort Smith, Arkansas, to the Arkansas Post Canal. These 95 facilities are being protected by these bank stabilization works from river mile 308 (Fort Smith, Arkansas) to river mile 22 (Pendleton Bridge-Arkansas Post Canal area).

Estimates, completed in November 1976, of prevention of loss of land by bank stabilization works amounted to slightly in excess of 6,000 acres over 290 river miles, see Table 7. Reach number one, the Fort Smith area, covering river miles 309 through 279 contained almost one-third, or 1950 acres, of the total area identified. A significant number of acres was identified in each of the eight reaches except within reach number three, the Dardanelle area, covering river miles 231 to 187, which had an insignificant amount of lands prevented from losses by bank stabilization works. This is probably due to the geographic or physical nature of this reach which made it unnecessary to provide any bank stabilization works.

Land Accruals - Usable land accruals from bank stabilization works have been identified to total almost 10,000 acres over the 290 river miles from just above Fort Smith, Arkansas, to the Arkansas Post Canal area (see Table 8). Of the eight reaches denoted, reach seven was identified as having no significant area of land accrual from bank stabilization works, while all other reaches have areas of land accruals ranging from 450 acres in reach five to 2560 acres in reach one.

Although a few areas in some reaches may be protected to the extent that it can be economically productive lands, these areas are still subject to flooding when flows are high. In areas where land accruals are

Table 6. ESTIMATED FUTURE AVERAGE ANNUAL BANK EROSION LOSSES

REACH	LAND	HWYS, PR, UTIL, & OTHER	LEVEE SET-BACKS	BANK PROTECTION WORKS	TOTAL DIRECT LOSSES	TOTAL DIRECT AND INDIRECT LOSSES
Mile 460.2 (mouth of Verdigris) to mile 361.8	\$ 72,900	\$290,400	\$ 28,000	-	\$ 391,300	\$ 408,200
Miles 361.8 to mile 111.2	235,000	192,600	126,500	\$ 31,500	585,600	628,800
Miles 111.2 to mile 0.0 (mouth)	27,400	170,800	208,300	158,200	564,700	571,700
TOTAL	\$335,300	\$653,800	\$362,800	\$189,700	\$1,541,600	\$1,608,700 ^{1/}

^{1/} Includes estimated future average annual losses in the reaches that will be inundated by the Webbers Falls, Short Mountain, Ozark and Dardanelle Reservoirs.

SOURCE: US Army Corps of Engineers Report Estimated Average Annual Erosion-Control Benefits that would Accrue to the Bank-Protection and Contration Works Included in Arkansas River Multiple-Purpose Plan, 1951.

Table 7. PREVENTION OF LOSS OF LAND FROM BANK EROSION BY BANK STABILIZATION WORK
(by reach and by area)
Little Rock District, 1976

REACH	GEOGRAPHIC LOCATION	NAVIGATION MILE (river mile)	ACCUMULATIVE AREA	
			AREA (acres)	AREA (acres)
1	Fort Smith, AR, to	309.6 - 279.0	1950	1950
2	Arbuckle Isl, Sebastian County, to	279.0 - 230.9	390	2340
3	Dardanelle Pool @ Spadra Creek, to	230.9 - 187.6	N/A	2340
4	AR River @ Petit Jean River, to	187.6 - 159.0	410	2750
5	AR River @ Cadron Creek, to	159.0 - 104.6	1240	3990
6	Chenault Isl, Pulaski County, to	104.6 - 85.5	620	4610
7	Below Lock & Dam 5, to	85.5 - 73.0	250	4860
8	Below Hwy 79 Bridge, to AR Post Canal	73.0 - 19.0	1190	6050
TOTAL			290.6	6050
				-

Table 8. USABLE LAND ACCRUALS FROM BANK STABILIZATION WORKS & CUTOFFS
(by reach and by area) 1976

REACH	NAVIGATION MILE (river miles)	AREA ACCRUED BY BANK STABILIZATION WORKS (acres)	AREA ACCRUED IN RIVER BEND CUTOFFS (acres)
1	309.6 - 279.0	1320	1240
2	279.0 - 230.9	670	920
3	230.9 - 187.6	170	990
4	187.6 - 159.0	290	610
5	159.0 - 104.6	280	170
6	104.6 - 85.5	260	2090
7	85.5 - 73.0	insignificant	insignificant
8	73.0 - 19.0	420	540
TOTAL	290.6	3410	6560

taking place, it is estimated that, although many areas may recover in productivity, not all will recover their full productivity. Also, this process will be a gradual action taking many years to recover previous productivity, even partially.

These land accruals have resulted in two ways, (1) areas accruing along and behind the dikes and/or revetments, and (2) areas accruing in river bend cutoffs associated with bank stabilization works and project construction. Deposition of dredge spoil has also resulted in accruals to these areas. As shown in Table 8, about one-third of the total accrual is associated with dikes and revetments and about two-thirds of the total accrual is associated with built-up areas in river bend cutoffs.

The estimated economic values accruing from the bank stabilization works were classified into the following categories:

Direct damages prevented:

- damages prevented to lands, buildings, roads, bridges and other capital improvements
- land damage (5,500 acres annually)
- cost of setback levees
- cost of bank protection

Indirect damages prevented:

- losses associated with interruption of business and gainful occupation

"The principal benefits, other than navigation, that would accrue to the Multiple-Purpose Plan because of bank-protection works provided therein would be the reduction of direct and indirect losses resulting from property damage, expenditures for set-back levees, cost of piecemeal bank-protection work, and loss of business and gainful occupation; benefits from increasing the rate of building up land by accretion; and the enhancement in land values that would result from the sense of security inspired by the bank-protection works." (U.S. Army Corps of Engineers, 1951)

Usable land accruals from bank stabilization works were estimated by Little Rock District personnel in 1976 to total about 3,400 acres, Table 6. These lands are expected to revert to a gallery forest providing protection with wildlife habitat. These lands will become part and parcel of the bank stabilization process and will serve partially to enhance the buffer zone between the river and the protected areas.

The remaining area accrued in the river band cutoffs, estimated by LRD in 1976 to be about 6,500 acres, is already or is expected to be

productive for agricultural row crops. The most likely crop expected for use on these lands is soybeans. Yields of soybeans from these lands are estimated to average about 25 bushels per acre. Yields may vary from year to year widely above and below this average in direct response to the soil productivity, and degree or length of inundation from rises in depth of river flows.

In addition to protected productive lands from damage by erosion, no additional levee setbacks have been required to date even though extremely high river flows have been experienced. No bridges, railroads, or utility crossings losses have occurred of significant consequence. Losses which were anticipated to take place under the without project conditions have not occurred with the project in place; therefore, it is concluded that the project is functioning as anticipated and the full range of damages is being prevented and the benefits from the project continue to accrue.

IV. SUMMARY AND CONCLUSIONS

1. Bank stabilization and channel rectification are integral features of the approved multiple-purpose plan of development of the Arkansas River. The capital costs of the bank stabilization works were \$119,300,000, or about 10 percent of the entire project cost of \$1.2 billion. The construction of the bank stabilization works has resulted in the achievement of its primary goal of a stable channel which is necessary for the navigation features of the project, and prevents damages to lands, levees, highways, pipelines, and other capital improvements along the River.

2. Economic effects of the bank stabilization have been significant and widespread. Millions of tons of commerce are shipped upon the waterway annually which allows millions of dollars in savings of transportation costs. These savings accrue from savings on tonnages shipped by waterway and from savings to shippers not using the waterway who enjoy reduced rates of other modes of transportation into or out of the area. Thousands of acres of productive agricultural lands are protected. Damages to highways, railroads, levees, utilities and to the navigation locks and dams are reduced or prevented amounting to thousands of dollars annually. In addition to those losses prevented from these bank stabilization works, indirect losses to business and gainful occupation have been reduced. Millions of dollars of investments have been made for economic developments, for transportation facilities, recreation facilities, and other facilities due in part to the stabilization works.

3. Almost 10,000 acres of land have been accrued from the project design and construction. An estimated 3400 acres behind the stabilization works, and almost 6600 acres of land area, have accrued in river bend cutoffs. Although some of these areas may recover productivity,

not all will recover their full productivity, and it will be a gradual process taking many years to recover that productivity even partially.

4. Bank stabilization works have had specific physical, environmental, and economic effects. The economic effects are far-reaching, including the local areas, the region, the Nation, as well as international impacts through trade. Stabilization works contribute significantly to the accrual of benefits which are obtained from this project. It is an essential feature allowing many of these benefits to accrue.

REFERENCES

Bank Stabilization Study

1. Schmidgall, Tasso, Maintenance Dredging on the Arkansas River, page 459, Rivers '76, Vol 1, American Society of Civil Engineers, 1976.
2. Arkansas River Basin; Arkansas, Oklahoma and Kansas; Navigation, Report of the Chief of Engineers, U.S. Army Corps of Engineers, 1973
3. Arkansas River and Tributaries, Arkansas and Oklahoma, 79th Congress, 2nd Session, House Document No. 758, July 30, 1946.
4. Environmental Effects of the Completed McClellan-Kerr Arkansas River Navigation System, 1978 by University of Arkansas, Fayetteville, AR and West Arkansas Community College, Fort Smith, AR, for Little Rock District, U.S. Army Corps of Engineers.
5. Estimated Average Annual Erosion-Control Benefits that Would Accrue to the Bank Protection and Contraction Works Included in the Arkansas River Multiple-Purpose Plan, U.S. Army Corps of Engineers, 1951.
6. McClellan-Kerr Arkansas River Navigation System, Arkansas and Oklahoma, pertinent data for testifying officer, 1 January 1973, U.S. Army Corps of Engineers, Little Rock District, and 6 January 1975.
7. Navigation Charts, McClellan-Kerr Arkansas River Navigation System, Catoosa, Oklahoma, To Mouth of White River, July 1976, U.S. Army Corps of Engineers Districts, Little Rock, Arkansas, and Tulsa, Oklahoma.
8. Report on Annual Activities of the Arkansas River Basin Coordinating Committee, prepared by U.S. Army Corps of Engineers, Southwestern Division, 1972-1978.
9. Water Resources Development in Arkansas, 1975, U.S. Army Corps of Engineers, Southwestern Division, Dallas, Texas.
10. Brochure, McClellan-Kerr Arkansas River Navigation System, Revised 1972, by U.S. Army Corps Engineers Districts, Little Rock, Arkansas, and Tulsa, Oklahoma.